DISCUSSION ON
"PROPAGATION"
AT THE CONVENTION ON THE BRITISH CONTRIBUTION TO TELEVISION, 29TH APRIL, 1952

Mr. G. Millington: Dr. Smith-Rose in his survey paper has reminded us that a successful television service does not depend only on having a high-power transmitter and a sensitive receiver, but also upon the nature of the propagation from the one to the other. The large bandwidth associated with high definition necessitates the use of very high radio frequencies and it is fortunate that the propagation of these frequencies is favourable to the attainment of a high-quality service.

In the days of the low-definition tests, attempts were made to transmit the signals to Australia, but it was obvious that the received pictures would be useless on account of multi-path effects. The use of the very high frequencies restricts the service area to the ground-wave range, although the paper by Messrs. Kitchen and Tremellen reminds us that even in television broadcasting we cannot entirely dismiss the effect of the ionosphere. It appears that at sunspot maxima the transmission of frequencies up to 50 Mc/s to great distances by F-layer reflection may cause mutual interference between television and other services sharing the same frequencies in different parts of the world.

It is sometimes difficult to decide whether long-distance reception at ranges of the order of 1 000 km, on frequencies in the range 40–60 Mc/s, takes place by reflection from an abnormal E layer or is due to the tropospheric effects described in the paper by Dr. Saxton. At the shorter distances, where anomalous propagation may be caused by the formation of a radio duct or by reflection from an inversion layer, the variable nature of the phenomenon precludes its being taken into account in assessing the service area of a television transmitter. In fact, Dr. Saxton's paper is a warning that such long-distance propagation is a liability and not an asset, adversely affecting the amount of common- or adjacent-channel working that can be employed in the television band.

So far as the use of relay links is concerned, there are technical advantages in using as high a frequency as possible and working well within the optical range, but for television broadcasting itself the use of as low a frequency as is compatible with high definition is desirable, in order to increase the service area beyond the strictly optical range. Moreover, the lower the frequency, the less severe will be the effects of diffraction behind hills and other obstacles. Even so, these effects can be very troublesome, causing large variations of field strength from one part of a town to another, as is shown in the paper by Messrs. Tagholm and Ross.

It would be interesting to know whether these authors have considered the method that has been tried by the R.C.A. in the United States,* namely the use of a local relay on the top of a hill to re-transmit the signal to people living in the shadow region. It may be that the best cure in the future for these television "blind spots" will be to build houses where a preliminary field-strength survey has shown that reception will be good.

I am particularly intrigued by the survey set described by Messrs. Bray and Corke, since the principle involved was used by Mr. Isted and myself in the model working on a 3-cm wavelength with which we demonstrated propagation across a land-sea boundary in the Institution lecture theatre two years ago. It is interesting to see that by careful design the method can be used over such large distances. I should like to ask the authors whether they have extended its use to lower frequencies. The fading analyser they describe is also a most useful tool designed to ease the problem of analysing the large quantity of data obtained in such surveys, although one needs to keep a flexible mind in deciding how to extract the maximum information in the time that can reasonably be given to the task.

Sir Noel Ashbridge in his Address yesterday hinted at the possible application of information theory to television by the removal of the redundancy that often exists in a picture. It will be interesting to know to what extent any proposals that are put forward may be conditioned by the propagation aspects that we are considering in this Session of the Convention.

Dr. A. J. Biggs: I have been somewhat concerned by the suggestion of the use of horizontal polarization for television transmission. We have had some general references to the improvement which may be obtained in respect of interference by operating some transmitters on horizontal polarization and some on vertical polarization. I want to ask whether any of the authors can give us any factual information as to how much improvement may be effected by this means, because I feel that the spurious methods of transmission involved at long distances may rotate the plane of polarization considerably.

Mr. L. Lewin: With reference to the paper by Messrs. Bray and Corke, I should like to say that we have made a considerable number of measurements on microwaves across the Firth of Forth, and one of the things that we have been doing is examining the effects of the reflected ray from the sea and its interference with the direct ray. We have developed a fair technique for this, involving, among other things, an aerial which moves moderately rapidly up and down its mast as the simplest means of ascertaining the vertical distribution of field strength. If the results are analysed in terms of a postulated curvature effect it is found that the vertical waveform of the distribution pattern can be explained in terms of it, and thence one can deduce an effective earth's radius. On top of this, the pattern itself moves up and down, and this is correlated directly with the tides.

When we first started we had to find out the heights and timing of the tides, but after we had got into the swing of it we could more or less tell what the tides were doing from the electrical measurements. The result suggests that, in conjunction with other experiments, this may be a method of telling the tidal variation in districts where it is not otherwise easily measurable.

Fig. 11 shows the variation of the received pattern, presumably on the assumption of no tides because the tides themselves move the whole thing backwards and forwards. The variation of (effective earth radius)/(actual earth radius) ratio is deduced to be from 0·5 to 5·0. Our experimental data over the course of a few weeks show that the range is very much greater. We believe that the figures will come down as low as 0·4 and, at the upper end, go up rapidly through high numbers to infinity, and then become negative. The significance of the negative values is purely that they fit into the formula; but if one imagines the earth turned

* Jones, E. T.: "Enlarging the Television Audience," *Broadcast News*, 1952, No. 67, p. 54.

inside out, one would be propagating across it on the inside. The actual figure for the curvature goes down as far as $-1 \cdot 0$. These are experimental values. It is useful to know them if one is designing, especially from the point of view of height-diversity reception, in order that the diversity spacing may be adequate to cover the extreme of the range.

During the course of the measurements we had no fading effect that was not explainable in terms of an effective earth radius, and the distribution was the sort of thing that one would expect, centring at the established value of about four-thirds.

I should like to put one question of a somewhat related character to Messrs. Tagholm and Ross, in connection with Fig. 9 of their paper. On the face of it, this curve shows all the phenomena associated with the beating between a direct ray and a reflected ray, but when one looks at the contour it would appear that there is a very high range of hills in the middle, and there is not even a direct ray—let alone a direct ray and a reflected ray—to cause interference. I should like to know whether the authors have an explanation as to why the set of ripples has come about. The depth of the ripples seems to be too great to permit of an interpretation in terms of ordinary diffraction effects.

Monsieur E. P. Courtillot: I should like to put a point to Dr. Smith-Rose with regard to vertical and horizontal polarization.

I should like to quote a paper concerning experiments on v.h.f. broadcasting frequency modulation published in the *Proceedings*.* Amplitude measurements were made at the receiving points in accordance with the two techniques and they indicated that there was a very important rotation of the polarization up to the point of obtaining equal field strength for vertical and horizontal polarization. If I agree with the author so far as the field near the transmitter is concerned, I am afraid that the interfering field at a considerable distance will have any polarization, and that it is somewhat preposterous to think that cross polarization will help in these conditions.

To take an example, does the author believe that the field generated by the transmitter at Kirk o'Shotts will still have a vertical polarization in Southampton, where it will interfere with the Isle of Wight transmitter radiating a field horizontally polarized?

There is also a point in regard to the paper by Messrs. Bray and Corke. The figure of $1 \cdot 0$ db has been quoted concerning the free-space transmission in the path AC, but the same figure for attenuation was not given to the path BC. I should like to know what the attenuation is in that case.

Mr. K. J. Easton: My remarks are also concerned with propagation and reception conditions well beyond the optical horizon, and they are mostly pertinent to Dr. Smith-Rose's paper.

The recent development of wired systems of television distribution has brought to light one or two factors which are not normally encountered in reception by ordinary domestic means.

Ignoring the question of fading, long-term and short-term, the chief factor affecting the quality of pictures received well beyond the official service area is the presence of noise—i.e. background circuit noise and man-made interference. When one is able to eliminate—or at least practically eliminate—these factors, as may be the case with wired systems of distribution, by using carefully sited high-gain aerial arrays and low-noise amplifiers, one finds in certain parts of the country (and it appears to apply only in certain parts of the country) that one is left with another type of interference which takes the form of random spots appearing on the picture, and this, so far as can be seen, is due to random static discharges in the atmosphere.

Recent work has shown that these discharges as picked up at the aerial are, in fact, random in a horizontal plane and do not therefore appear to be due to cosmic noise or some such extra-territorial source having a definite direction of arrival, but the erection of arrays having good vertical directivity does materially reduce the interference from this source. This seems to suggest that this interference comes from strata above the earth—possibly several thousand feet above it—and not from layers of the atmosphere which are in close proximity to the earth. I should like to know whether any of the authors can give us information about this particular form of interference and whether any work has been done on this form of static discharge—if in fact it is an atmospheric discharge.

Another point on which I should like some information concerns the possibility of horizontal refraction of the received signals at considerable distances from the transmitter when crossing coastal boundaries at very high angles of incidence amounting almost to grazing angles. In recent work we have found that when receiving transmissions from one B.B.C. transmitter at some distance, using arrays of aerials with high gain and high directivity, any doubling of the horizontal aperture of the array does not give the anticipated 3-db increase in signal strength, and certain tests have suggested that this result may be due to the fact that the horizontal arrival angle of the signal is off the axis of the aerial, possibly by as much as 15° or 20°. The particular aerial site concerned is receiving its signals from the transmitter at what is certainly grazing angle along the coast. The main path is along the sea, and quite close to the receiving site the path crosses the coast at an angle of probably not more than 5 or 10°. I should like to know whether there is any information concerning such apparent horizontal refraction.

Mr. K. I. Khoury: My main interest is in propagation above 800 Mc/s. I should like to know whether any measurements have been carried out with respect to these frequencies in view of the application of microwaves to television broadcasting, and also whether or not there is any special interference pattern in a built-up area. It seems that in the United States there have been experiments in the use of microwave frequencies for broadcasting television signals. I should like to know whether there are any published results about such propagation other than for point-to-point transmission.

THE AUTHORS' REPLIES TO THE ABOVE DISCUSSION

Drs. R. L. Smith-Rose and J. A. Saxton (*in reply*): Several speakers in the discussion have referred to the question of wave polarization and to the discrimination that can be achieved by the use of vertical and horizontal polarization respectively. It has been demonstrated experimentally that in suitable open-field conditions the signal obtained on a dipole receiving vertically polarized radiation can be reduced by 36 db by rotating the dipole into the horizontal position. In a normal reception area, however, the polarization of the arriving radiation is distorted, owing to the effects of re-radiation from conductors which are either not wholly vertical or not in the horizontal median plane of the dipole. In such circumstances the discrimination obtained by using a dipole set at right angles to the polarization of the incoming radiation varies over a wide range, but experience shows that the mean discrimination obtained in different parts of a built-up or residential area is about 10 db. Experience also indicates that this discrimination is likely to be maintained well beyond the limits of the normal service area.

With reference to Mr. Easton's remarks on the bending of waves in crossing a coastline, we have no experience of deviations

* KIRKE, H. L., ROWDEN, R. A., and ROSS, G. I.: "A V.H.F. Field-Strength Survey," *Proceedings I.E.E.*, 1951, 98, Part III, p. 343.

of the order quoted. Is it possible that this represents an incorrect deduction from the experimental observations described, or that the radiation actually received on the aerial system included some re-radiation from surrounding objects, which need not be in the immediate vicinity of the receiver? As is mentioned in Dr. Smith-Rose's paper, investigators in this field have detected waves reflected from a gas-holder and a range of hills at distances of 12–30 km. Except under very good conditions, it is not easy to distinguish between such effects and the possible deviations of the waves in crossing a coastal boundary. It is thought that all such effects are not likely to be a serious factor in normal television reception.

In reply to Mr. Khoury, the characteristics of wave propagation at the frequencies in the neighbourhood of 800 Mc/s is under investigation in various parts of the world, but little in the way of published literature exists at present. Reference may, however, be made to two papers.*

Messrs. F. A. Kitchen and **K. W. Tremellen** (*in reply*): In reply to Mr. Millington, we are of the opinion that at distances of the order of 1 000 km long-distance reception on frequencies in the range 40–60 Mc/s is most likely to arise as a result of reflection from an abnormal E region, rather than of scattering from inhomogeneities in the troposphere. However, the latter effect will usually predominate at shorter distances. Recently, some new information on long-distance propagation of v.h.f. waves via the ionosphere, which adds support to our view, has been published.† It appears that continuous propagation via the ionosphere takes place owing to scattering from turbulent eddies in the E region, in a manner similar to that discussed by Dr. Saxton regarding the troposphere, provided that adequate power is radiated and the receiving system is sufficiently sensitive. Whilst the ionospheric mode of propagation is continuous, there are variations in intensity of the received signal associated with time of day, season, geomagnetic and meteor activity. In particular, there is usually an enhancement in the received signal during sudden ionospheric disturbances of the type which result in fade-outs on high frequencies. The range of distances affected by the phenomenon is similar to that quoted in our paper for conventional sporadic-E reflection. Although it appears unlikely that this particular manifestation of abnormal E-region ionization will be a great source of interference to television reception in the immediate future, owing to the very high effective radiated powers required, commercial application of the phenomenon could be troublesome from this point of view.

* Guy, R. F., Serbert, J. L., and Smith, F. W.: "Experimental U.H.F. Television Station in the Bridgeport, Connecticut, Area," *RCA Review*, 1950, **11**, p. 55.
Guy, R. F.: "Investigation of U.H.F. Television Transmission and Reception in the Bridgeport, Connecticut, Area," *ibid.*, 1951, **12**, p. 98.

† Bailey, D. K., Bateman, R., Berkner, L. V., Booker, H. G., Montgomery, G. F., Purcell, E. M., Salisbury, W. W., and Wiesner, J. B.: "A New Kind of Radio Propagation at Very High Frequencies observable over Long Distances," *Physical Review*, 1952, **86**, p. 141.

Messrs. L. F. Tagholm and **G. I. Ross** (*in reply*): Mr. Lewin suggests that the oscillatory nature of the height/gain curve in Fig. 9 is not due to the interaction between a direct ray and an indirect ray because of the screening effect of the range of hills between transmitter and receiver.

As stated in the paper, the anomalous height/gain is due to an extra ground reflection near to the transmitter site, in addition to that normally associated with the space wave, and it would be apparent at the receiving point whether the range of hills were there or not; any variation of field strength at the top of the range of hills will be observed in the region beyond it.

Mr. Millington suggests a method, as tried by the R.C.A., of using local relays at the top of the hills to re-transmit the signal to people in the shadow region by means of land lines. We agree that this is one method of distributing the programme, but it is a problem rather outside the scope of the paper.

Messrs. W. J. Bray and **R. L. Corke** (*in reply*): It would appear that the technique suggested by Mr. Lewin, in which the rise and fall of the tide is predicted from microwave measurements, is mainly applicable to short oversea paths (e.g. 20 miles or less), and under conditions such that the refractive index of the atmosphere is relatively stable between high and low tide.

On the relatively long (39·5 mile) oversea path (Belfast–Stranraer) discussed in Section 5.2, it has not been found practicable to correlate the fading with tidal variations with any certainty; it is agreed that such an effect must be present to a certain extent, but this is generally masked by fading due to changes in the refractive index of the atmosphere.

The relatively small range of fading on the low-path BC (see Fig. 9) suggests that values of $K = Re/R$ as low as $+0{\cdot}4$ and as high as $-1{\cdot}0$ (after passing through infinity) are very exceptional; a typical range would appear to be $+0{\cdot}9$ through infinity to $-8{\cdot}0$, these values being exceeded for 99% and 1% of the time respectively.

In reply to Monsieur Courtillot, the measured path attenuation of the low path BC is about 1 db less than the calculated free-space value, measured at times when fading was almost completely absent.

In reply to Mr. Millington, it is doubtful whether the simple technique for measuring path attenuation described in the paper can usefully be extended below about 1 000 Mc/s, since the transmitter power required increases with the square of the wavelength for aerials of a given aperture; the main field of usefulness is therefore in the centimetric range of wavelengths.